SPAWNING HABITAT ENHANCEMENT AS MITIGATION FOR BANK PROTECTION PROJECTS

Description

Spawning habitat is comprised of streambed gravel, the flow of water over and through the gravel. Spawning habitat includes any areas with appropriate substrate and hydraulic conditions for spawning, and adjacent cover habitat such as pools or woody debris. More importantly, it's the hydraulics of the channel that sorts the gravel and creates the conditions desired for spawning. Because spawning habitat is based on complex channel processes, spawning habitat may be difficult, if not impossible, to create in some situations. For this reason, spawning habitat replacement as a mitigation technique has only limited application and should be done carefully and with full understanding of the potential biological implications.

Mitigation of spawning habitat, degraded through changes in land use, must occur at broad watershed scale compared to mitigation for specific bank protection projects. For instance, mitigation for spawning habitat that is degraded in a watershed that has been "clearcut" requires a comprehensive investigation of changes in hydrology, sediment production transport among other factors.

Bank-protection projects can affect spawning habitat both directly and indirectly. Direct effects, which are often irreversible, include burying or covering spawning habitat with a bank protection project or during construction activities. Channelization projects that shorten or abandon a portion of the channel also result in the reduction or elimination of spawning habitat. Indirect effects can include disruption of gravel recruitment from eroding banks and alteration of natural, channel migration processes that create spawning habitat. Removing or reducing streambank and channel complexity can result in changes to the naturally occurring gravel-sorting process. Bank hardening can also result in lost opportunity by not allowing development of side channels and sloughs that often provide excellent spawning and rearing conditions.

Application

Mitigation for damaged or degraded spawning habitats resulting from installation of bank-protection techniques might include creation of in-stream habitat, off-channel habitat, spawning-gravel supplementation, and/or cleaning spawning habitat that has been contaminated with fine sediment (Figures 6-2 and 6-3). Mitigation can be conducted at a specific site to correct and enhance localized conditions, or it can integrate stream- and sediment-transport processes for a larger-scale effect.

Designing projects that provide spawning habitat can be approached in two ways. One is to develop spawning criteria or suitability curves, and attempt to maintain a bed elevation using gravel of the proper size that will have acceptable depths and velocities at design flows.[1] This method is generally not practical except where flow is controlled (e.g., off-channel spawning areas and spring channels). The second, more common and preferred approach, is to mimic natural conditions and encourage stream processes that produce localized scour zones and tailouts with sorted gravels. The tailout of a pool provides a continuum of velocities and depths with changing flows, creating suitable holding and spawning habitat for a variety of fish species. It is crucial to understand stream hydrology and local hydraulic conditions when undertaking a project that creates or enhances spawning habitat. It is the hydraulics that ultimately sorts and deposits gravel into spawning habitat. Hydrology and the supply of gravel to the site is also critical. A clear understanding of objectives comes from site and reach limitations. Are limitations caused by channel character such as low recruitment of debris that cannot create habitat? Are limitations created by a lack of spawning gravel source? Site-specific projects are often unsuccessful, or have only limited success, because the designer did not consider or understand stream processes. An appreciation of sediment transport dynamics within the watershed and at the site is critical to project success. For instance, projects relying on gravel supplementation can appear successful immediately after construction only to be destroyed after a high-flow event.

Promotion of Spawning Habitat Adjacent to Bank Protection

The best bank-protection techniques that also protect spawning habitat are those that maintain or create diversity in the hydraulic characteristics along the streambank. This, in turn, leads to creation of more complex structures, which then develop scour holes, enable gravel sorting in the tailout, and provide complex cover. Features such as log jams, which provide diversity and protect the bank, can actually mitigate their own impacts (Figure 6-1). An exception to the use of large, complex structures in large rivers is where the bank is immediately adjacent to a known spawning area used by mass-spawning fish like pink or chum salmon. In that instance, a structure that is set back into the bank or a log revetment may have fewer impacts to spawning habitat.

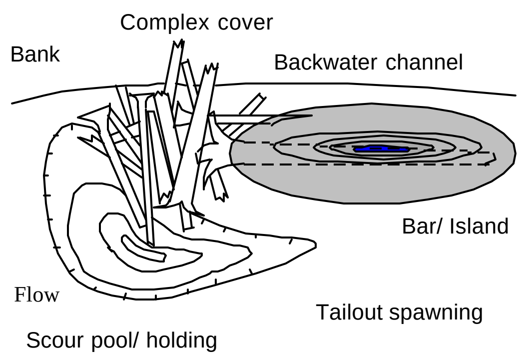

Figure 1. Log jam and habitat diversity

In-Channel Structures

Some locations, such as constricted channels, are not appropriate for large, in-channel structures. For these sites, partial- or full-spanning bed controls, such as porous weirs and grade controls , may be the most appropriate method to retain the gravel needed to form spawning pads. Drop structures normally result in sediment deposition upstream of the structure and a creation of a gravel bar downstream at the tailout of the plunge pool. These drop structures are typically made of logs or large boulders. They are usually not appropriate for large or low-gradient channels that have well-developed riffle-pool morphology. Low-gradient channels that have a consistent and reliable source of groundwater generally make excellent locations for creating gravel spawning-pads because they do not typically experience high flows that could scour away placed gravel, and they have an abundance of rearing area.

A channel may have an abundance of spawning gravel thatis not being used because of the lack of cover for adult fish. In that instance, placing pieces of stable, large, woody debris either in the bank or in the channel as cover structures will mitigate for some bank protection impacts. The cover structure must be large and complex enough to create and maintain a scour hole and stable enough to remain as long as the life of the bank-protection project. Cover logs can also be place on the bank to span existing local scour holes.

Off-Channel Habitat

Another form of mitigation for bank protection is off-site construction of a side channel with spawning habitat. This may be as simple as re-connecting an abandoned side channel or oxbow, or it may involve the excavation of a new channel on a well-vegetated river bar. This technique has been widely used in Washington State and British Columbia.[2] See Chapter 6,*Off-Channel Spawning and Rearing* for more information.

Spawning Gravel Supplementation

Supplementation -- the addition of spawning gravel to a stream -- can increase usable habitat. The intent of supplementation is that the added gravel is a source of gravel that becomes hydraulically distributed in such a way that it creates as a spawning habitat. The mechanisms of gravel and sediment transport in the watershed must be understood for a project like this to be successful (see the appendices on Hydrology and Hydraulics). A reasonable estimate of gravel retention and/or distribution is critical to project success. Spawning gravel may be added to a channel in a variety of ways, including using a helicopter, conveyor belt or a dump truck. It can also be deposited simply by placing a pile of properly sized gravel along the streambank and allowing high flows to entrain and distribute the gravel in the channel. In that case, the added gravel might be either placed to mimic an eroding gravel bank or a gravel bar. Mitigation may require adding new gravel periodically.

Supplementation is usually undertaken in situations where recruitment of gravel is limited, and a shortage of spawning habitat has been documented. Examples include urbanized streams that have been armored extensively and channels affected by reservoirs. It is the only measure that can provide mitigation for the loss of a gravel source.

Cleaning Spawning Habitat

A variety of techniques have been used to reduce levels of fine-sediment deposition within spawning gravel. Ideally, techniques should be employed that remove and directly replace fine-grained sediment with clean course gravels. Typically, gravel-cleaning techniques are useful only when a streambed has been adversely impacted by a single event or by a situation that has been corrected so recontamination won't occur. Rivers and streams with chronic, non-point-source pollution are not good candidates for gravel cleaning.

Rehabilitation of spawning gravels has usually been conducted on a relatively small scale in discrete reaches of a river. The simpler methods of gravel cleaning used in the past involved the use of heavy equipment such as a bulldozer, backhoe, or front-end loader to physically disturb the substrate. These methods are most successful at reducing fine-sediment concentrations if conducted during relatively high stream flows. They aren't generally acceptable however due to the release of sediment and potential for contamination of other spawning habitat downstream. A channel bed is less stable following this type of cleaning since the channel hydraulics will redistribute the bed material during subsequent high flows. R. J. Gerke[3] supervised the successful use of a bulldozer in cleaning spawning beds in several Washington rivers that have suffered from heavy siltation caused by landslides. On the Cedar River, 29,000 square meters of gravels were cleaned using a bulldozer. About 3,000 sockeye salmon and 50 chinook salmon spawned following the cleaning operation. A section of the Entiat River in Washington was also successfully cleaned using a bulldozer, according to D. A. Wilson.[4] J. R. West reported that spawning by chinook salmon increased in Scott River in Northern California after gravels were cleaned there with a bulldozer.[5]

Another approach to the rehabilitation of spawning gravels incorporates the use of a hydraulic flushing action to mobilize and collect fine sediments. The "Riffle Sifter," developed in 1963 by the U.S. Forest Service, was the first machine designed to hydraulically clean sediment-choked spawning areas. The Riffle Sifter flushes fine sediments from the substrate by injecting a high-speed jet of water into the stream bed through a series of pipes. The apparatus then collects the fine sediments through a suction system and jets them onto the floodplain. The Riffle Sifter has been shown to remove up to 65 percent of the particles smaller than 0.4 mm.[6] However, it has developed several mechanical problems in the course of cleaning in natural streambeds.[7]

The "Gravel Gertie" was developed in 1979 by Washington Department of Fish and Wildlife as a more advanced version of a hydraulic gravel cleaning machine.[8] The

Gravel Gertie is mounted on a low-bearing pressure tracked vehicle that drives through the riffle during operation. The hydraulic cleaning action of the Gravel Gertie uses a vertical jet of water, which is directed towards the streambed to flush out fine sediments. A suction system within a rectangular collection hood removes fines from stream flow. The Gravel Gertie was field tested on the Palouse River in northern Idaho and on Kennedy Creek and several other streams in Western Washington. Effective cleaning was accomplished to substrate depths of 12 inches. All of these streams showed a decrease in the percentage of fines after one pass, with reduction of fine sediments (<0.841 mm) ranging from 3 to 78 percent. These techniques are recommended only where material cannot effectively be removed and replaced.

Emergency

The creation of spawning habitat is rarely conducted under emergency conditions. Construction and enhancement of spawning habitat is typically conducted under low- or moderate- flow conditions. Careful design integrates the full consideration of stream hydrology and hydraulic conditions necessary to create and maintain the desired habitats. This is typically not advisable or even possible in an emergency situation.

Effects

Modifications to channel characteristics by the addition of spawning gravel or gravel retention structures can have unanticipated effects on banks and adjacent channel segments (see the techniques described in this chapter called *Channel Modifications*, *Porous Weirs*, and *Drop Structures*, and Appendix 6, *Fluvial Geomorphology*).

Design

Use of Large, Woody Debris to Enhance Spawning

The enhancement of spawning habitat often relies on the placement of large, woody debris to create the desired hydraulic conditions for sorting and retaining adequate quantity and quality of gravel (Figures 6-2 and 6-3). A log jam concentrates energy by acting as either a constriction, or an obstruction, resulting in the creation of a scour pool with the tailout providing spawning habitat. Siting of log jams must be carefully planned because of their potential to grow and alter the existing channel (see the technique described in this chapter called *Engineered Debris Jams* and Appendix 9, *Anchoring and Large, Woody Debris*).

Spawning Pads

Spawning pads are usually installed in streams less than 40 feet wide. They are created by either building a channel constriction or a drop structure across the channel, then placing a specified mix of spawning gravel upstream and/or downstream of the structure or allowing native gravel to deposit during high flows. Either structure creates a backwater upstream and a pool and tailout downstream that can collect gravel. The upstream gravel placement can also be designed to feed gravel to the tailout area. The channel constriction can create more diversity and intra-gravel flow than a cross-channel weir. It also has a much lower risk of creating a fish-passage barrier.

Spawning pads might be necessary where natural, woody debris has been removed, and no structure exists within the stream channel to retain gravel in stable bars. They are usually built as a series of drop structures. Spacing between structures is based on channel gradient and the height of drop at each structure. The drop should be one foot or less during all flows occurring during periods of fish migration to facilitate fish passage. If upstream juvenile fish passage is necessary, the drop required may be as small as six inches. However, structures with small drops are not as effective at sorting downstream gravel. In addition, the lower hydraulic head results in less intra-gravel flow. A potential risk with spawning pads is that spawners are often attracted to the newly placed gravel before it has had a chance to distribute hydraulically and stabilize. The eggs may not survive if the gravel in the spawning pad shifts during the first flood flows. Several high flows are needed to stabilize the spawning pad.

Channel constrictions can be used effectively to create spawning pads, but they should be considered only with a clear understanding of the dynamics of channel instability. Constrictions, as described elsewhere in these guidelines, can create a backwater condition resulting in gravel deposition and, ultimately, leading to channel reconfiguration, a situation that creates spawning habitat but can jeopardize bank stability. These dynamic processes are what naturally create spawning habitat. Constriction spawning pads usually only constrict the flow at moderate flood levels when gravel sorting occurs. They are generally constructed as low structures that will not constrict the channel during large floods.

A channel constriction is more effective in low-gradient, spring-fed channels than a cross-channel structure. A channel constriction should be designed to increase velocities enough to keep fine sediment flushed out of gravels, maintain a tailout, and be attractive to spawners. Spawning may occur in the constriction or at the tailout area. The spacing of constrictors is based on the channel gradient and the degree of backwatering developed by the constrictor. A common mistake is to place constrictors too close together, resulting in the backwatering of the upper constrictor, which, in turn leads to reducing velocities, thereby negating the intent of the application. Constriction design, including spacing and size, can be accomplished using either hydraulic models or through trial and error in the field.

An advantage of porous weirs and drop structures in creating spawning habitat is the high intra-gravel flow developed through the structure and bed upstream. However, this can be a problem if the stream experiences very low flow, and the entire flow goes subsurface. The standard, log drop structure technique developed by the Washington Department of Fish and Wildlife is a good solution that has been effective and durable in many Washington streams over the last 15 years.[9]

Gravel Supplementation

Gravel supplementation can provide an alternative means of mitigating for degraded or lost spawning habitats (Figures 6-2 and 6-3). In reaches that are limited in gravel recruitment, a streambank or a gravel bar can be constructed of gravel and designed to erode, which provides a source of spawning gravel. However, because the lack of cohesion in a gravel-constructed bank, this application, if not well planned, can result in bank erosion. Other techniques add gravel directly to the stream and rely on high flows to distribute the gravels. A designer must consider sediment transport, hydrology, and hydraulic conditions as well as channel morphology and structure. Refer to Appendix 6, *Fluvial Geomorphology* for further discussion of gravel transport.

Groundwater Channels

Groundwater channels, or off-channel, groundwater-fed channels, can be developed for both spawning and off-channel rearing habitat. These are low-gradient channels with low flows. Spawning usually occurs either at points of upwelling or on constructed spawning pads. If the native bed material is not the appropriate size, it will need to be replaced or supplemented with spawning gravel. Refer to the technique described in this chapter called *Off-Channel Spawning and Rearing* for information on the design of groundwater channels.

Biological Considerations

Mitigation Requirements for the Technique

Mitigation for construction-related impacts may be required depending on the type of construction technique(s) used. Riparian habitats can be impacted by type of equipment and site access. Careful planning and the proper use of installation equipment (helicopter, conveyor, etc.) to distribute gravel can significantly reduce potential impacts.

Dewatering -- isolating the area under construction and removing water from it using a coffer dam system -- is required to control turbidity associated with in-channel excavation.

Mitigation Benefits Provided by the Technique

Spawning habitats are often the most difficult habitats to replace. Their stability and longevity are important to whether or not future generations of fish can and will use them. Longevity as habitat includes appropriate sorting of material and intra-gravel hydraulics. For this reason, it is crucial that the habitat-restoration project be designed in a way that it is self-maintaining.

Carefully planned and properly constructed in-stream and off-channel spawning habitats can also mitigate for lost or damaged juvenile rearing habitats and, to a lesser extent, adult holding habitats. Projects that integrate certain structural aspects, such as large woody debris, can produce diverse habitat for a variety of life stages and species of fish.

Refer to Chapter 5 selection matrices for further discussion of applicable mitigation scenarios for spawning habitat.

Risk

Habitat

Poorly designed and constructed projects may retain their utility for only a short period. Material (gravel, debris, boulders) selection is critical to the maintenance of the project over time. Newly placed spawning habitat is attractive to fish as perceived spawning habitat. If material is not properly placed or has not had time to settle, however, it can shift or even wash away after the fish have spawned, causing a loss of eggs. Improperly sized gravels may also flush out, filling downstream habitats. Poorly anchored large, woody debris may become dislodged, lose function, and damage downstream habitats Refer to Appendix 9, *Anchoring and Large, Woody Debris Placement* for more information.

Infrastructure

With the exception of poorly installed large, woody debris becoming dislodged, spawning-habitat enhancement poses minimal risk to existing infrastructure. There is some risk if channel constrictions or drop structures are placed without consideration or proper understanding of backwater and flooding implications, however.

Reliability/Uncertainty in Technique

Reliability and success is greatly increased when the finished project mimics natural conditions and allows for natural channel process and gravel mobility. Salmonids' spawning needs are highly particular, and replicating the necessary conditions is critical to project success. The creation of desirable spawning habitat for adults is in vain if conditions during egg incubation are unstable.

Construction Considerations

Materials Required

Large, woody debris elements should be sufficiently large to achieve the desired hydraulic effect to create and maintain spawning habitat. Small or poorly anchored woody debris may become dislodged and jeopardize the project. Similarly, boulders should be selected that are sufficiently large to remain stable.

The selection of appropriately sized spawning gravels is also critical to the success of the project. Sizing of material should be first determined by hydraulic characteristics and then by spawning characteristics. Refer to Appendix 5, *Hydraulics* for further information on sediment transport. Rounded rock, uniformly graded from 0.25 to 3 inches in diameter, provides ideal spawning habitat for many salmonids in the Northwest. Specific mixes vary for sizes and species of fish and hydraulic conditions. The larger material in the mix is more for the purpose of providing stability than as spawning gravel. In some applications, it may be appropriate to augment spawning gravels with larger materials to add initial stability. Angular or crushed gravels should not be used as spawning substrate.

It may be appropriate to add a small fraction of larger material to provide some initial stability especially when the material is expected to be naturally sorted such as in higher gradient reaches and when creating spawning habitats that have lengths and widths similar to the full channel width. Sizing of material should be first determined by the hydraulic characteristics of the site and secondarily by its spawning characteristics.

Historically, construction materials have included logs, boulders, lumber and gabions. Gabions are not recommended because of abrasion by bedload during floods, damage by debris, and their tendency to deform or roll in response to downstream scour. Boulder drop structures can experience some of the same difficulties if not designed properly. For See the technique described in this chapter called *Drop Structures* for information about designing these structures.

Timing Considerations

Construction timing should avoid critical periods in salmonid life history such as spawning, migration and egg incubation. In-stream work windows vary among fish species and streams. Contact the Washington Department of Fish and Wildlife's Area Habitat Biologist for information on work windows (see Appendix 2, Washington Department of Fish and Wildlife Regional Offices). Further discussion of construction timing and dewatering can also be found in Appendix 13, *Construction Considerations*.

Ideally, newly constructed projects should experience a high-flow event prior to their use as spawning habitat. High flows allow the placed gravel to sort and stabilize prior to it use for spawning.

Cost

Cost is highly variable in spawning enhancement projects. Availability and delivery of materials contribute to variability in costs. A cost-saving option used by the Washington Department of Fish and Wildlife for obtain spawning substrate is to sort gravels near the site. This technique involves the use of a mobile sorting operation positioned to be close to the project site. Delivery costs are significantly reduced using this method. Sorted and washed gravels may cost $20 to $40 per cubic yard. Large, woody debris may cost between $200 and $750 per log.

Dewatering of a project site can add significant cost to a project. Dewatering costs are greatly affected by the size of the channel and other site-specific factors.

For further discussion of costs, refer to Appendix 12, *Cost of Techniques*.

Operation and Maintenance

If properly designed and constructed, a spawning habitat mitigation project should not require any maintenance. Gravel supplementation projects must be periodically supplied with additional gravel.

Monitoring Considerations

Biological monitoring provides the ultimate measures of project success. For a comprehensive review of habitat monitoring protocols, refer to the Washington Department of Fish and Wildlife work in progress, *Inventory and Monitoring of Salmon Habitat in the Pacific Northwest*.[10] Monitoring the project for its integrity as a spawning site will likely require a more comprehensive schedule than that required for the integrity of the structures.

In addition to biological monitoring, monitoring the physical conditions is important to documenting project performance. Measurements of the degree of scour, distribution and abundance of gravel, gravel sorting, channel movement, and the condition of retentions structures are recommended elements of a monitoring plan. Constructed spawning habitat, including bed forms and woody debris, can be carefully surveyed immediately after construction and again after initial high flows to document changes that might affect spawning success. Spawning chains or other devices intended for measurement of spawning-gravel stability and scour can also be used. However, it is very difficult to quantify impacts of bed instability near hydraulic structures, since the hydraulics will be quite varied around the structure.

Examples

Debris Jams

Dungeness River
Little Hoko River
Cowlitz River near Packwood
Deep Creek (Straits of Juan De Fuca)

Spawning Pads

Hurd Creek (Sequim)
Moxlie Creek (Olympia)

Groundwater Channels

Skagit River - Park slough, Illabot channel, Taylor Channel, Newhalem ponds
Hoh River - Young’s slough, Lewis channel

Gravel Supplementation

Sacramento River, Redding CA.

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